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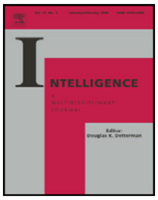

Aging trajectories of fluid intelligence in late life: The influence of age, practice and childhood IQ on Raven's Progressive Matrices

R.T. Staff [a,b,*], M.J. Hogan [c], L.J. Whalley [d]

[a] NHS Grampian, Aberdeen, United Kingdom
[b] Aberdeen Biomedical Imaging Centre, University of Aberdeen, Aberdeen, United Kingdom
[c] Department of Psychology, NUI, Galway, Ireland
[d] Institute of Applied Health Sciences, University of Aberdeen, United Kingdom

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ABSTRACT

Background: Examining the trajectory of cognitive abilities in late life is difficult because of the long time required for significant change to occur and the confounding influences of baseline ability, cohort, dropout and practice.
Purpose: The aim is to describe cognitive trajectories in late life by estimating the influence of age and practice and by accounting for the potential confounding attributable to 'Flynn' and 'Mathew' effects.
Methods: We examine repeated measures of fluid intelligence (IQ) in 751 volunteers' ages 62 through 83 years sampled from the Aberdeen birth cohorts of 1921 and 1936 for whom archived childhood IQ data provided a rare insight into early life ability. Aging trajectories in fluid intelligence were estimated using Raven's Standardized Progressive Matrices (RPM). Data were analyzed using linear mixed models.
Results: We estimate that on average RPM decreases annually by over one-half point (age effect). There is also an initial increase of about two points from the first to second test occasion that the test is taken and this may be attributed to practice. Comparisons between birth cohorts suggest that the 'Flynn' effect influences our data and that its size was significantly larger in late life. We found no evidence of the 'Mathew' effect in late life.
Conclusions: Cognitive trajectory of fluid ability in late life is a mixture of practice and decline. The influence of practice appears to be greatest after the first repeat testing. Modeling late life decline in this way will enable intervention studies to be performed in normal and prodromal dementia populations more efficiently.

1. Introduction

Examining the trajectory of cognitive abilities in late life is challenging due to the long time period required for significant change to occur and the confounding influence of baseline ability, age, cohort, dropout and practice. The objectives of this study are to quantify normative aging trajectories and to identify potential predictors of these trajectories. In order to overcome challenges and obtain proper inferences, assumptions were made about the influence and mechanism of different predictors of cognitive ability change trajectories in late life.

One challenge in estimating longitudinal change in late life is that trajectories of change may be influenced by cohort effects. Cohort differences in socioeconomic circumstances, education,

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Abbreviations: RPM, Raven's Progressive Matrices; MHT, Moray House Test; *P*, Practice.

[*] Corresponding author at: Aberdeen Royal Infirmary, NHS Grampian, Foresterhill, Aberdeen AB25 2ZD, United Kingdom. Tel.: +44 1224 552239.

E-mail address: r.staff@abdn.ac.uk (R.T. Staff).

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job complexity, leisure and cognitive pursuits may influence trajectories of change and result in different conclusions as regards normative patterns of change for different generations and historical periods. For example, the "Flynn effect" (Skirbekk, Stonawski, Bonsang, & Staudinger, 2013) describes a large-scale cohort effect that has been observed in most countries, whereby performance on IQ tests has improved with each decade of the 20th century. The 'Flynn effect' has been estimated to be of the order of 3–4 IQ points for successive decades of the twentieth century (Brouwers, Van De Vijver, & Van Hemert, 2009). This observation that, coupled with other cohort differences, may influence patterns of age-related decline reported in cross-sectional and longitudinal studies. For example, using data from the Seattle Longitudinal Study Gerstorf, Ram, Hoppmann, Willis, and Schaie (2011) reported less steep rates of cognitive aging between 50 and 80 years of age favoring the later born cohorts.

Estimating trajectories of cognitive change in late life is also challenging as a result of, dropout effects. Dropout occurs for the unavoidable reasons of death or illness and from voluntary withdrawal (Rabbitt, Lunn, & Wong, 2006). In addition, longitudinal studies by their nature involve repeated testing of individuals which introduces the additional influence of practice. That is, an individual may perform better because of familiarity with a test and testing environment. Practice effects of this type may be greater in individuals with higher original intelligence (IQ). Research using delayed growth models to evaluate patterns of skill acquisition suggests that baseline ability predicts rate of learning (Voelkle, Wittmann, & Ackerman, 2006). Longitudinal studies of IQ in children also provide evidence of the "Matthew effect" (Merton, 1968; Stanovich, 1986) whereby children with higher baseline IQ show more of an increase in IQ with repeated testing over time (Shaywitz et al., 1995). However, no study has examined if childhood IQ and/or adult ability predicts larger practice effects in the context of longitudinal analysis of cognitive change in older adults. In other words, it is unclear if the "Matthew effect" extends to old age trajectories of change.

Improvement with practice has been demonstrated by using a wide range of tests and in a variety of circumstances. Bartels, Wegrzyn, Wiedl, Ackermann, and Ehrenreich (2010) observed practice effects were stronger in the early phase than the late phase of high-frequency repetitive (1–6 monthly intervals) cognitive testing of healthy individuals. A plateau in performance followed with little or no effect of practice through repeating the test. Ferrer, Salthouse, Stewart, and Schwartz (2004) sought to fit different shaped practice effects on longitudinal estimates of memory, space related abilities and speed of processing measures recorded at approximate yearly intervals. The shapes examined represent an initial practice model where the improvement is observed on the second testing occasion with negligible improvement thereafter. The second model represents a linear practice with equal amounts of improvements made on each testing occasion. Thirdly, the delayed practice model predicts small amounts of improvement are made initially and rates of improvement increase on each subsequent testing occasion. The form that this practice learning curve takes with our data and circumstances is unclear.

In addition to modeling the influence of practice, the separation of practice from the effect of age is a considerable analytical challenge. The need to model separate effects for age and practice are widely discussed (Ferrer et al., 2004; Rabbitt, Diggle, Holland, & Mcinnes, 2004; Salthouse, Schroeder, & Ferrer, 2004). When practice effects exist as a result of repeated assessments, ignoring the retest component will underestimate any age effect. When the frequency of testing (the interval between test and retest) is fixed, separating practice from decline is difficult since the unit of time and the interval of practice are essentially equivalent. Mcardle and Woodcock (1997) have proposed a model capable of handling different test intervals that permits the separation of practice and age.

Trajectories of cognitive change in late life can differ for different cognitive ability measures. Fluid ability is the capacity to think logically and solve problems in novel situations, independent of acquired knowledge (Horn & Cattell, 1966). Fluid ability typically peaks in young adulthood and may steadily decline thereafter.

Here, we use linear mixed modeling to estimate the influences of childhood IQ, age and retest practice on fluid ability in a well characterized sample of older adults with archived IQ scores at age 11 years and whose fluid ability was tested between ages 62 and 83 years on up to five occasions. We use a previously published age/practice model (Ferrer, Salthouse, Mcardle, Stewart, & Schwartz, 2005) and hypothesize that (1) age has an overall significant negative effect on ability and (2) practice a significant positive influence on performance on Raven's Standardized Progressive Matrices (RPM), a robust test of fluid intelligence. We include IQ test scores at age 11 years to extend the Ferrer et al. model and hypothesize (3) that higher childhood intelligence and/or greater adult premorbid ability predicts greater practice improvement. This hypothesis essentially tests the presences of the 'Matthew effect' in late life. By including childhood ability, we adjust for potentially confounding influence of the "Flynn effect" on our data. In addition we also examine the influences of different practice models on our results. Consistent with previous research we further hypothesize that (4) ability at entry into the study is associated with greater practice improvements, and (5) older age at entry into the study is associated with less practice improvement. Overall, the approach adopted in this study will allow us to examine the relationship between childhood ability, ability at entry into the study, age at entry into the study, decline with age and practice improvement.

2. Methods

2.1. The sample

All data were provided by the Aberdeen Birth Cohorts of 1921 and 1936, an extended description of samples recruitment and data acquisition is given in Whalley et al. (2011). Following guidelines provided by the local ethics of research committee (University of Aberdeen and NHS-Grampian), volunteers gave written informed consent to a longitudinal observational study of brain aging and health. Briefly, RPM data were collected longitudinally from two identically recruited cohorts between January 1998 and December 2011. For each cohort the number of recruitment and follow-up measurements for each study year is shown in Table 1. RPM scores were recorded up to five times in each participant between ages 62 and 83 years. All data were collected between January 1998